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Full Length Research Paper

Comparative study between effects of ethanol extract of Zingiber officinale and Atorvastatine on lipid profile in rats

Abdelkrim Berroukche*, Abdelkrim Attaoui and Mustafa Loth

Laboratory of BioToxicology, Pharmacognosy and Biological Recycling of Plants Biology Department, Faculty of Sciences, Moulay Tahar University, Saida 20000, Algeria.

***Zingiber officinale* is known for its cholesterol-lowering and antioxidant properties. The use of traditional medicine reduces the use of drugs with a risk of toxicity. This study aims to assess the effects of ethanol extract of *Z. officinale* and atorvastatin on lipid parameters in rats fed with high-fat diet. The experiment was carried out on 40 rats during 9 weeks. The animals were divided into 4 groups; group 1 (normal healthy controls), group 2 (hypercholesterolemic diet controls), group 3 (treated with ethanol extract of *Z. official* at 500 mg / kg / day) and group 4 (treated with Atorvastatin at 20 mg/kg/day). It has been shown, respectively in groups 3 and 4, a stable body weight (289 vs 282 g) and a highly significant reduction of cholesterol (295.9 vs 275.1 mg/dl), total triglycerides (46.8 vs 41.9 mg/dl) and LDL (278.2 vs 259.1 mg/dl), but not a significant increase in HDL (8.6 vs 7.8 mg/dl). Results showed that *Z. officinale* is similar to Atorvastatin as a cholesterol-lowering agent in the treatment of patients exposed to risk of obesity and cardiovascular disease. Therefore, combination regimens containing ginger and low dose of statins could be advantageous in treating hypercholesterolemic patients.**

Key words: *Zingiber officinale*, cholesterol, antioxidant, Atorvastatine, cardiovascular disease.

INTRODUCTION

Metabolic syndrome, including obesity and dyslipidaemia that predisposes type 2 diabetes, is becoming more prevalent in many countries (Ascaso and Carmena, 2015). In developed countries metabolic syndrome appears to affect around 25 % of the population (Salas et al., 2014). The modern lifestyle of increased intake of high-calorie food contributes to the rising prevalence of obesity and type 2 diabetes (Isordia-Salas et al., 2012; Salas et al., 2014). Epidemiological studies also revealed that 90% of all patients with type 2 diabetes have been overweight, and indicated that obesity is a strong risk factor, and cause of type 2 diabetes and associated with metabolic disturbances (Salas et al., 2014). The therapeutic options such as dietary modification or a

*Corresponding author. E-mail: kerroum1967@yahoo.fr. Tel: 00213798520868: Fax: 0021348515830.

combination of synthetic antidiabetic, hypolipidaemic drugs have their own limitations and undesirable side-effects (Heeba and Abd-Elghany, 2010). There is an increased demand to search and evaluate traditional approaches for the treatment of metabolic disorders, particularly the use of herbal medicines. *Zingiber officinale* is widely used around the world in foods as a spice (Das et al., 2012). For centuries, it has been an important ingredient in herbal medicines for the treatment of rheumatism, nervous diseases, asthma, stroke, and diabetes (Kim et al., 2012). The major chemical constituents of essential oil *Z. officinale* rhizome include various terpenoids such as shogaols, paradols and zingerone (Jelled et al., 2015).

In laboratory experiments, ethanolic extract of *Z. officinale* has been shown to reduce plasma lipids in cholesterol-fed hyperlipidaemic rabbits (Zhang et al., 2011). It has been shown previously that long term dietary feeding of ginger has hypoglycemic and hypolipidemic effects in rats (Zhang et al., 2011). Besides, Z officinale has also been shown to reduce lipid parameters in streptozotocin induced diabetic rats (Ibrahim and Shathly, 2015).

Statins are group of drugs that have been recognized as the most efficient drugs for the treatment of hyperlipidemia. Atorvastatin differs from other statins in that it has a longer action and presents active metabolites which are biotransformed mainly by cytochrome P3A4 in the liver. Previous studies have reported severe AT-induced hepatotoxicity (Heeba and Abd-Elghany, 2010). Natural products and their active principles, as sources for new drug discovery and treatment of diseases, have attracted attention in recent years. Herbs and spices are generally considered safe and proved to be effective against various human ailments (Heeba and Abd-Elghany, 2010). *Zingiber officinale* is one of the commonly used medicinal plants around the world (Heeba and Abd-Elghany, 2010). In this study, we aim to compare the effects of *Zingiber officinale* and Atorvastaine on lipid profile in rats fed with high fat diet.

MATERIAL AND METHOD

Plant material and extraction

Zingiber officinale rhizomes were purchased from a local market in Saida, Algeria, during February 2013, and authenticated by Prof. M. Terras of the Biology Department, Moulay Tahar University, Saida, Algeria. The plant was dried in the shade. The dried rhizomes were powdered mechanically. Pulverised *Z. officinale* rhizomes (3 kg) were added to 5 L of 95% ethanol at room temperature for 7 days. The ethanol extract of *Zingiber officinale* rhizomes (EEZO) was evaporated to dryness under reduced pressure, for the total elimination of alcohol, followed by lyophilisation, yielding 500 g of dry residue. The EEZO was kept at - 20 °C until use and suspended in distilled water.

Preparation of animals

Male Wistar rats, 2 months of age and with mean weight of 180 g, were obtained from the Laboratory Animal of Biology Department (University of Oran, Algeria). They were maintained in a temperature-controlled room (25 ± 1°C) on a 12:12 h light–dark cycle in the Biology Department, University of Saida, Algeria. The rats were divided into four groups (10 rats / group); group 1 as a normal healthy control (NHC), group 2 as pathogenic hypercholesterolemic diet control (HDC), group 3 as HDC and treated with EEZO, and group 4 as HDC treated with Atorvastatine (ATV). Food and water were available ad libitum. Regular rat diet with 19% protein, 58% carbohydrate, and 7% fat was used as the maintenance and control diet. Hypercholesterolemia was induced by force feeding orally of 0.5 g cholesterol in 5 ml hydrogenated vegetable oil (Hemn et al., 2015) for 9 weeks along with normal rats feed in groups 2, 3 and 4. All animal procedures were performed according to the Guide for the Care and Use of Laboratory Animals as well as the guidelines of the Animal Welfare Act. The EEZO (500 mg / kg b.w. in 2 % water) and ATV (20 mg / kg b.w.) were administrated daily orally from the 7th week to groups 3 and 4, respectively. Group 2 served as pathogenic hypercholesterolemic diet control (HCD) and group 1 was kept as a normal healthy control (NHC).

Body weight data and biochemical parameter analysis

The daily body weights were recorded in all groups of rats during 9 weeks. After having heated the tail of the animal to cause vasodilation of the veins, an incision was practiced at the extremity of the tail (Sanchez et al., 2010). The blood samples were collected after every week during all the period of experimentation. Diagnostic kits (VIDAS) for the measurement of total cholesterol (TC) and total triglycerides (TG) were purchased from Bio Merieux Company (Lyon, France). Lipid parameters as TC, TG and high density lipoprotein-cholesterol (HDL-C) were measured using the semi-automatic analyzer mini-VIDAS, while low density lipoprotein-cholesterol (LDL-C) and very low density lipoprotein-cholesterol (VLDL-C) were measured using the Friedewald equations:

$$LDL = TC - HDL - (TG/5)$$
$$VLDL = TG/5$$

Statistical analysis

Data are expressed as the difference between the initial and final values (± SD) with a value of *p < 0.05* considered statistically significant. Statistical evaluation was performed by one way analysis of variance (ANOVA). The Tukey-test was used for all pairwise multiple comparisons of the mean ranks of the treatment groups. All analysis was carried out with the statistical software SigmaPlot *version 11.0.*

RESULTS

The changes in the mean body weight of the experimental groups of rats during 9 weeks treatment period are shown in Table 1. During the period of experimentation, there was no significant difference in the body weight in

Table 1. Weight and biochemical parameters of pathogenic hypercholesterolemic diet control (HDC) and normal healthy control (NHC) rats.

Parameters (Mean ± SD)	Group 1 (NHC)	Group 2 (HDC)	Group 3 (HCD+EEZO)	Group 4 (HDC+ATV)
Body weight (g)	226.33±22.68	282.22±69.6	289.44±57.75	280.55±54.34
Serum TC (mg/dL)	186.1±8.01	*327.84±105.83	295.9±84.71	275.16±85.57
Serum HDL-C (mg/dL)	***14.75±0.84	8.01±1.93	8.26±2.5	7.86±2.33
Serum LDL-C (mg/dL)	*166±6.74	307.7±101.1	287.26±83.82	259.08±86.38
Serum VLDL-C (mg/dL)	5.32±0.83	*10.42±4.63	9.36±3.37	8.38±3.11
Serum TG (mg/dL)	26.63±4.18	*52.14±23.67	46.84±16.87	41.93±15.55

SD: standard deviation; NHC: normal healthy control; HDC: hypercholesterolemic diet control; EEZO: ethanol extract *Zingiber officinale*; ATV: atorvastatine, TC: total-cholesterol; HDL-C: high density lipoprotein-cholesterol; LDL-C: low density lipoprotein-cholesterol, VLDL-C: very low density lipoprotein-cholesterol; TG: total-triglyceride.***: $p = 0,0009$ (highly significant different). *: $p = 0.02$ (statistically different).

Figure 1. Variation of body weight gain in rats feed high fat diet and treated with ethanol extract of *Zingiber officinale* rhizomes (EEZO) and Atorvastatine (ATV).

different groups ($p = 0.08$) (Figure 1). Table 1 shows that serum T-cholesterol concentration was higher in three groups of rats (HDC, HDC+EEZO and HDC+ATV) than NHC rats, whereas these concentrations were not significantly different among the 3 groups of rats mentioned previously. The solution of the EEZO (500 mg / kg b.w. / day), administrated to rats from the 7th week, had induced a significantly decrease of serum T-C in comparison with hypocholesterolemic diet control rats untreated with OOZE ($p = 0.008$) (Figure 2).

Atorvastatine drug (20 mg / kg b.w./ day), administrated to animals from the 7th week, caused a high significantly reduction of serum TC level in comparison with the HDC rats, but the decrease of this parameter was not higher than that of HDC rats treated with OOZE. The mean values of serum HDL-C concentrations observed in

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Figure 2. Variation of serum Total-Cholesterol concentration in rats feed high fat diet and treated with ethanol extract of *Zingiber officinale* rhizomes (EEZO) and Atorvastatine (ATV). GR1: NHC, GR2: HDC, GR3: HDC+EEZO and GR4: HDC+ATV.

different groups of rats are shown in Table 1. The serum HDL concentrations before the treatments were not significantly different among the HDC, (HDC+EEZO) and (HDC+ATV) groups of rats (Figure 3). Serum HDL-C levels, among 3 groups of animals cited previously, were significantly lower than that of NHC rats. The treatment of hypercholesterolemic diet animals of groups 3 and 4, respectively with EEZO (500 mg / kg b.w./day) and ATV (20 mg / kg / day) from the 7th week, had significantly caused an increased serum HDL-C level in comparison with the group 2 (HDC untreated) ($p = 0.0009$). Whereas NHC rats, fed with low-fat diet, showed significantly increased serum HDL-C levels (Figure 3). The levels of LDL-C as calculated by Friedewald's equation in various groups of experimental rats are shown in Table 1. The serum LDL-C concentrations, before the treatments, were not statistically different among the groups 2, 3 and 4 (Figure 4). Rats fed high-fat diet (HDC) showed significant elevation of serum LDL-C compared with the serum LDL of normal control rats ($p = 0.002$) at the end

of 6 weeks treatment. But the pathogenic hyper-cholesterolemic diet rats, treated separately with EEZO and ATV from the 7th week of experimental period, showed high significant reduction in LDL-C compared with the high-fat diet-fed control (HDC). Furthermore, the serum LDL-C concentrations, in EEZO treated group, were not significantly different from the normal control group at the end of the treatment. The EEZO and ATV produced significant anti-hyperlipidaemic action. The test drug and standard drug significantly reduced the levels of serum VLDL-C ($p = 0.025$) (Figure 5) and total-triglycerides (TG) ($p = 0.026$) (Figure 6) when compared with group 2, that is, pathogenic hypercholesterolemic diet control (HDC).

DISCUSSION

In this study, we investigated the protective effects of ethanolic extract of *Z. officinale* in high-fat diet-fed rats, a

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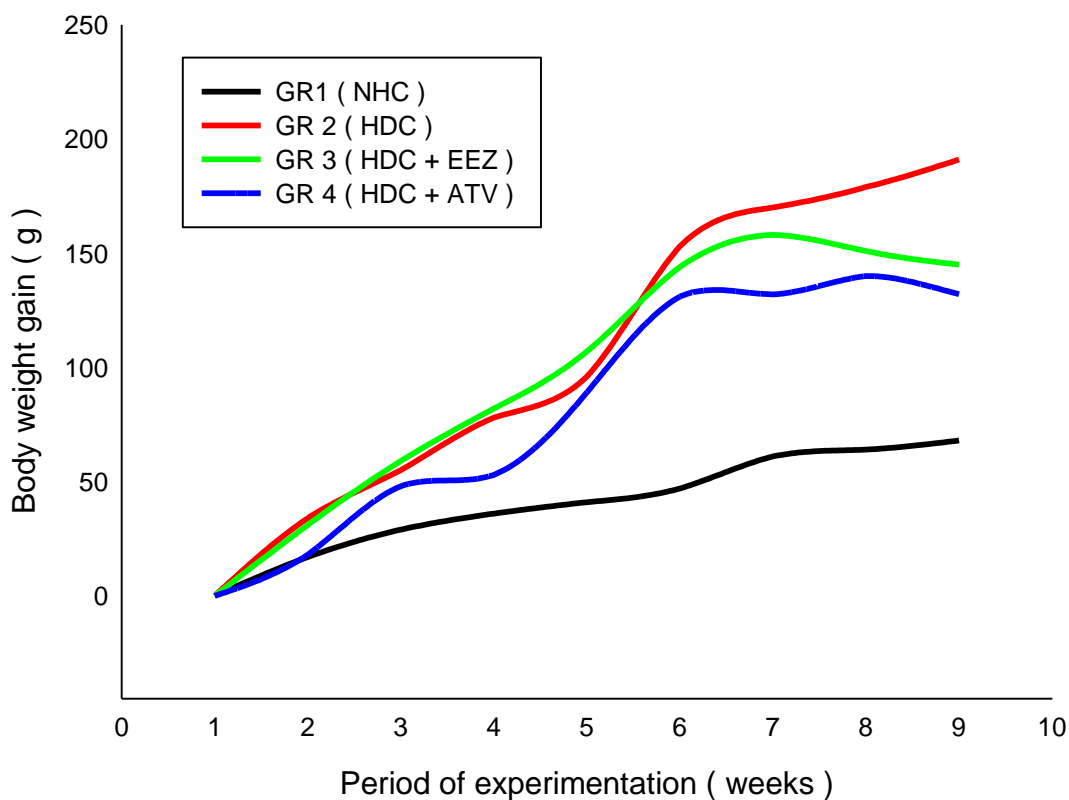**Figure 3.** Variation of serum HDL-Cholesterol concentration in rats feed high fat diet and treated with ethanol extract of *Zingiber officinale* rhizomes (EEZO) and Atorvastatine (ATV).

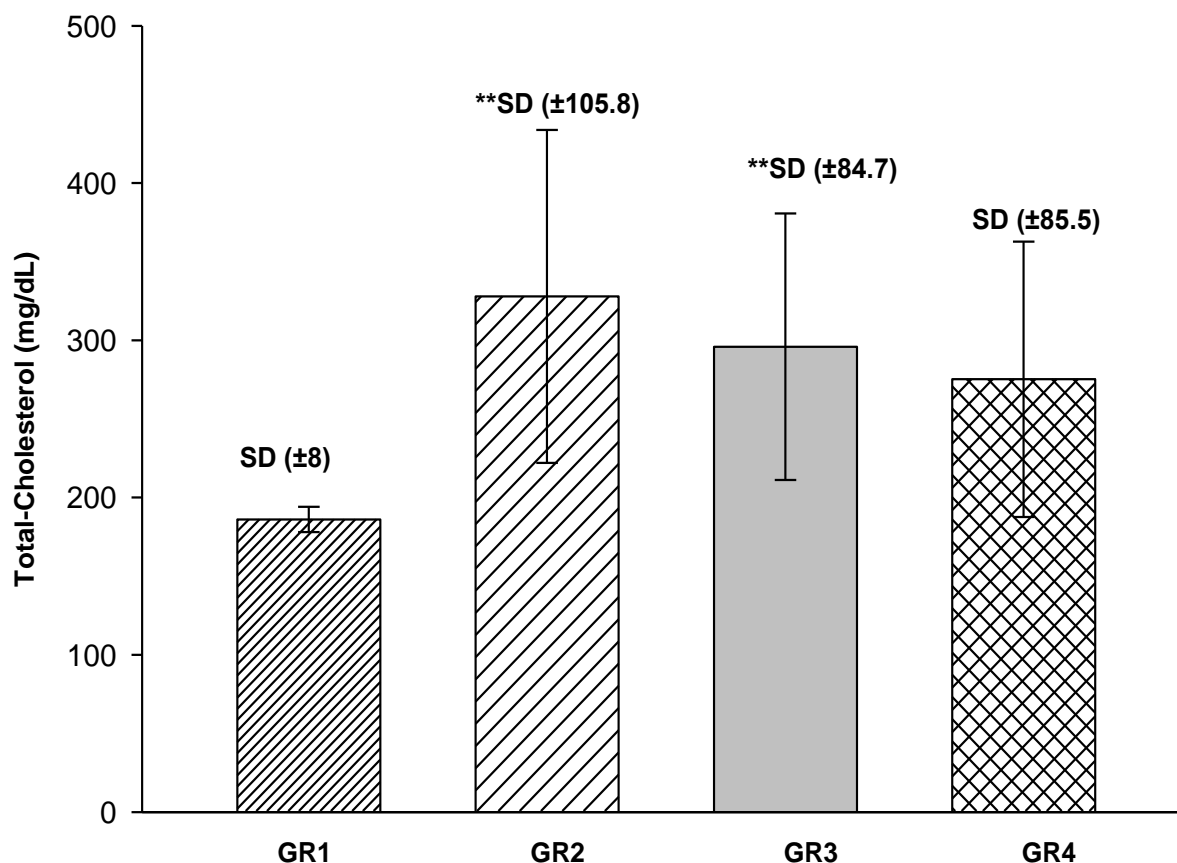**Figure 4.** Variation of serum LDL-Cholesterol concentration in rats feed high fat diet and treated with ethanol extract of *Zingiber officinale* rhizomes (EEZO) and Atorvastatine (ATV).

Figure 5. Variation of serum VLDL-Cholesterol concentration in rats feed high fat diet and treated with ethanol extract of *Zingiber officinale* rhizomes (EEZO) and Atorvastatine (ATV).

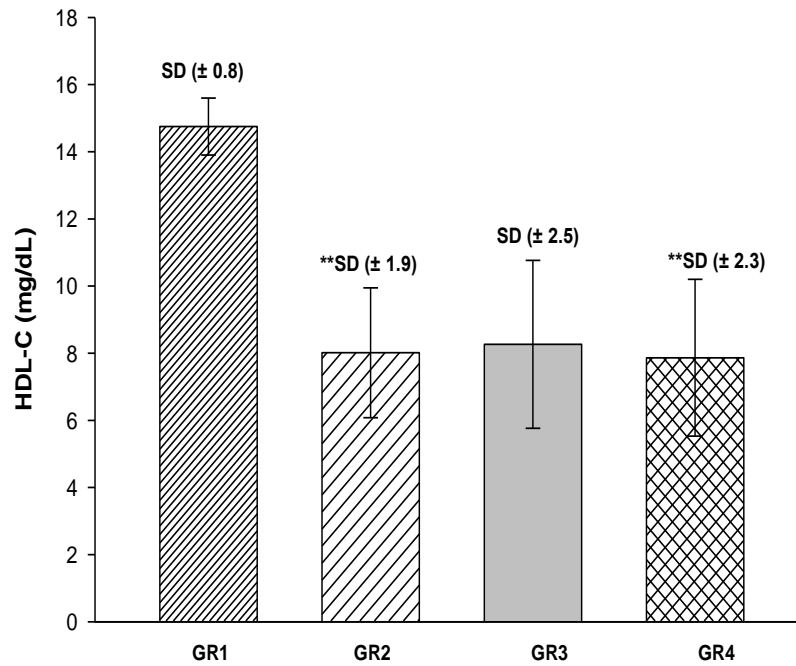**Figure 6.** Variation of serum Total-Triglyceride concentration in rats feed high fat diet and treated with ethanol extract of *Zingiber officinale* rhizomes (EEZO) and Atorvastatine (ATV).
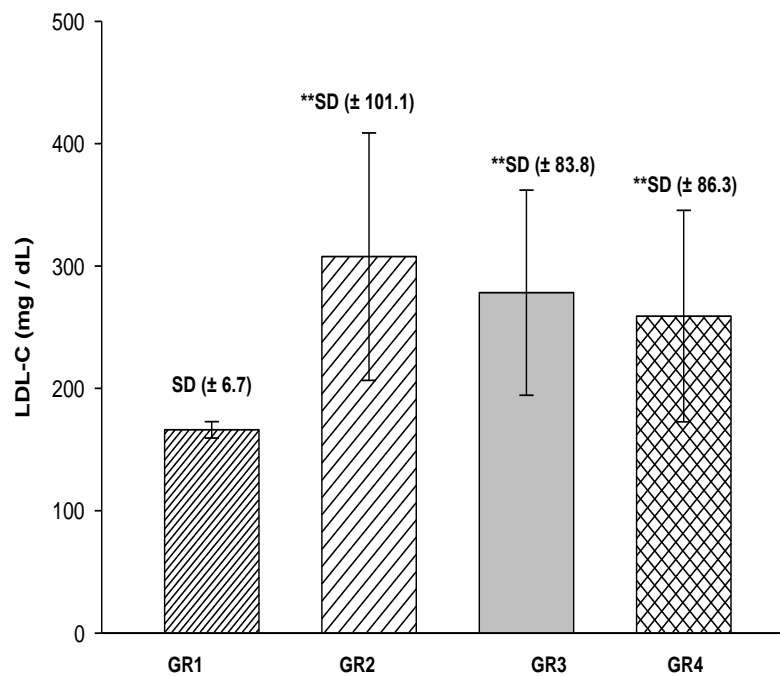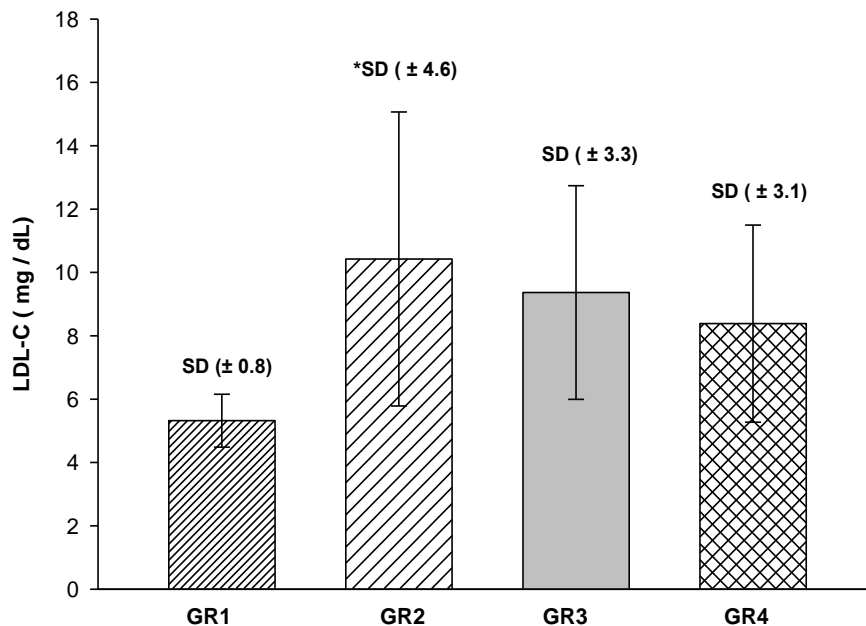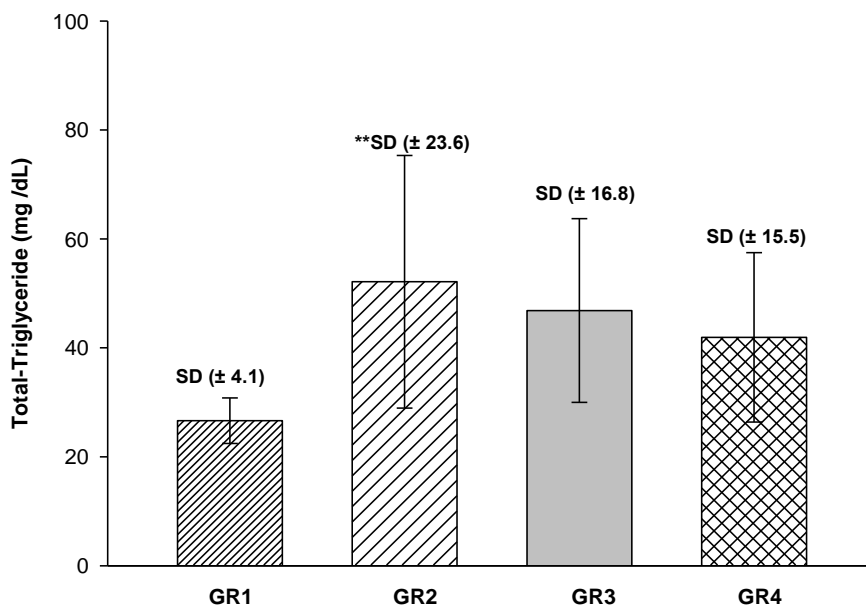
metabolic model of hyperlipidaemia, which according to Heeba and Abd-Elghany (2010), is similar to human metabolic syndrome. Dyslipidaemia is the most important risk factor contributing to the development of

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atherosclerosis in type 2 diabetes (Meaney et al., 2013). The development of metabolic syndrome is influenced by a combination of genetic and environmental factors. Among the environmental factors, long-term high-fat intake is most intensively studied because of its contribution to the development of metabolic syndrome in human beings and rodents (Salas et al., 2014).

Results of this study are consistent with results of previous research works that have shown the anti-hypercholesterolemic effects of *Z. officinale* (Prasad et al., 2012). The ethanolic extract of *Zingiber officinale* rhizome, administered to animals with the high-fat diet effectively reduced the serum total cholesterol, LDL-C, total triglycerides and raised HDL-C. Earlier studies (Al-Noory et al., 2013) have demonstrated that *Z. officinale* through its activity on hepatic cholesterol-7α-hydroxylase, stimulates the conversion of hepatic cholesterol to bile acids. More recently, Poorrostami et al. (2014) found that *Z. officinale* increased the faecal excretion of cholesterol, suggesting that this species may block the absorption of cholesterol in the gut. The increase in LDL-C may be due to the reduced expression or activity of the LDL-receptor sites in response to high-fat diet treatment as advocated by Brown and Goldstein (2012). Essential oil of *Z. officinale* is rich in antioxidants and anti-inflammatory components as α-zingiberene, β-sesquiphellandrene, curcumene, β-phellandrene, β-bisabolene and camphene (Yanagisawa et al., 2012). The powdered *Z. officinale* rhizomes contains aromatic components mainly gingerol and shogaols (Li et al, 2012; Asami et al., 2010). Pharmacological activities, mainly hypolipidimic effects, have been attributed to molecules of gingerol (Yanagisawa et al., 2012). Statins, overhung by Atorvastatin, slow the progression of hyperlipidemia. It has been suggested as an association of low HDL-C with a greater cardiovascular risk. This drug, as inhibitor of transfer of cholesteryl ester protein, increases from 40 to 60% of serum HDL-C and moderately reduces the serum LDL-C (Larach et al., 2013) **.** Although atorvastatin drug is rich in synthetic bioactive molecules and acts quickly and precisely at specific molecules, *Zingiber officinale* showed comparable effects on hyperlipidemia or hypercholesterolemia.

Conclusion

The ethanolic extract of *Zingiber officinale* protects from the high-fat diet induced metabolic disorders by strongly decreasing the body weight gain, protection from hyperlipidaemic conditions. The results confirm that *Z. officinale* is an antihyperlipidaemic agent, and possesses a potential medicinal value. Its traditional consumption in foods as a spice is beneficial in the prevention of metabolic disorders caused by high-fat diet. However,

further detailed clinical studies are required to establish its application.

Conflict of interests

The authors have not declared any conflict of interest.

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Full Length Research Paper

Essential oil constituents and *in vitro* antimicrobial activity of the root of *Mondia whitei* (Hook. F.) Skeels (Periplocaceae)

Idayat T. Gbadamosi[1]* and Sherifat A. Aboaba[2]

[1]Department of Botany, University of Ibadan, Oyo State, Nigeria.
[2]Department of Chemistry, University of Ibadan, Oyo State, Nigeria.

The composition of the essential oil of the root of *Mondia whitei* was analysed by gas chromatography-mass spectrometry (GC/MS). The agar-well diffusion technique was used for the antimicrobial assay of the oil against nine clinical pathogenic organisms viz. *Bacillus cereus, Escherichia coli, Candida albicans, Klebsiella pneumoniae, Pseudomonas aeruginosa, Proteus mirabilis, Salmonella typhi, Staphylococccus aureus* and *Streptococcus pyogenes*. Twenty-eight compounds representing 99.92% of the essential oil were characterized. The major constituents of the oil were (E)-2-hexen-1-ol (25.96%), heptacosane (20.94%), phytol (15.60%), 1-hexanol (8.94%), (E)-2-hexenal (4.29%) and 2-hydroxy-p-anisaldehyde (4.21%). At 10^6 cfu/ml inoculums concentration, the oil was most active against *E. coli* (50.0 mm) and *S. aureus* (48.3 mm) and least active on *C. albicans* (15.0 mm). Generally, the oil exhibited significant (P ≤ 0.05) antimicrobial activity against the test organisms. The observed antimicrobial activity justify the ethnomedicinal uses of *M. whitei* in Nigeria.

Key words: Essential oil, *Mondia whitei*, root, (E)-2-hexen-1-ol, pathogenic organisms, antimicrobial assay.

INTRODUCTION

Mondia whitei is a climbing shrub medicinally used in tropical Africa. The root and root bark have a vanilla-like odour. The roots are valuable as aphrodisiac, to prevent premature ejaculation, increase sperm production and generally, to treat sexual weakness. A decoction or infusion of the roots is widely used to treat malaria, gastro-intestinal problems, pains and as restorative and appetite stimulant (Gill, 1992; Burkill, 1997). As food, the pulverised bark of *M. whitei* is eaten with fish or peanuts in Democratic Republic of Congo. The fresh or dried leaves are cooked with peanut butter, and eaten as a vegetable in Central and East Africa. In Nigeria and Uganda, dried powdered leaves are added to food as condiment. Due to the fragrance or vanilla-like odour of the root, the dried powdered roots are used in magico-religious mixture in Gabon (Burkill, 1997).

The *in vitro* antioxidant and antimicrobial activities of the ethanol extracts of the leaf and root of *M. whitei* have

*Corresponding author. E-mail: gita4me2004@yahoo.com.

been earlier reported (Gbadamosi and Erinoso, 2015). Although, the aromatic roots of the plant are extensively used in tropical Africa for therapeutic purposes, there is a dearth of information on its active compounds and bioactivities of such compounds. In view of the ethno-medicinal importance of *M. whitei* and the need to further harness its medicinal potential, this study characterized the essential oil of the plant and screened the oil for antimicrobial activity against nine clinical pathogenic microorganisms.

MATERIALS AND METHODS

Source and identification of plant materials

M. whitei whole plants were collected from a forest near Oyo town, Oyo State, Nigeria. The plant was identified (UIH 22405) at the University of Ibadan Herbarium (UIH). The roots were cut from the whole plant, air dried at room temperature, ground into powder and stored in air tight bottle for further experiments.

Essential oil analysis

The essential oil was extracted from 300 g of the powdered sample by hydrodistillation method in an all glass Clevenger-type apparatus fitted to a 5 L round bottom flask and sitted in a heating mantle for 3 h (British Pharmacopoeia, 1980). The essential oil distilled was collected over water from the transparent side arm of the Clevenger apparatus, dried over anhydrous sodium sulphate and then the oil was stored in a vial and kept refrigerated at 4°C until analysis. The composition of the essential oils was determined by gas chromatography-mass spectrometry (GC/MS) using an Agilent 7890N GC with Agilent mass detector Triple Quad 7000A in EI mode at 70 eV (m/z range 40 – 600 amu) and an Agilent Chem Station data system. The GC column was equipped with an HP-5MS column (30 m x 250 μm x 0.25 μm) a split-split less injector heated at 200°C and a flame ionization detector (FID) at 230°C. The oven temperature was programmed as follows: Initial temperature 40°C for 5 min, increased 5 °C/min to 180°C for 6 min and then 10°C/min to 280°C for 12 min. Helium was the carrier gas at flow rate of 1 mL/min. The injection volume was 2.0 μL (split ratio 1:20). The components were identified by comparison of their mass spectra with NIST 1998 library data of the GC-MS system as well as by comparison of their retention indices (RI) with the relevant literature data (Adams, 2004). The relative amount of each individual component of the essential oil was expressed as the percentage of the peak area relative to the total peak area. RI value of each component was determined relative to the retention times of a homologous n-alkane series with linear interpolation on the HP-5MS column.

Antimicrobial assay of *Mondia whitei* root oil

The antimicrobial assay was carried out using agar well diffusion method (Hood et al., 2003). All overnight cultures of organisms were grown in nutrient broth at 35 ± 2°C for 18 h. 1 ml of the inoculums (10^6cfu/ml) was added to 19 mL of sterile nutrient agar. The mixture was poured into Petri-dishes and allowed to solidify. From each plate, two wells were cut using 6 mm cork borer. Each well was filled with 50 μL of the oil or sterile nutrient broth (control). The plates were incubated at 35 ± 2°C for 18 - 38 h. Zones of inhibition were recorded in millimetres (mm). Each experiment was carried out twice.

Statistical analysis

The analysis of variance and comparison of means of data of antimicrobial activity were carried out using Statistical Analysis System (SAS). Means of values were assessed for significance at P ≤ 0.05 by Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Twenty-eight (28) compounds were detected by GC-SM analysis (Table 1). The identified compounds were characterized by a lofty amount of (E)-2-hexen-1-ol (25.96%), heptacosane (20.94%), phytol (15.60%), 1-hexanol (8.94%), (E)-2-hexenal (4.29%) and 2-hydroxy-p-anisaldehyde (4.21%). Others were linalool (3.02%), cyclohexylmethane (2.09%), 3-octanol (2.68%), 1-octen-3-ol (2.24%), β-ionone (2.1%), m-xylene (1.56%), 3-octanone (1.37%) and 1-octen-3-one (1.25%). 13 out of the 28 compounds recorded <1% concentration of compounds. The two major compounds in the essential oil were (E)-2-hexen-1-ol (25.96%) and heptacosane (20.94%) and the medicinal value of the plant could be attributed to their presence in the oil. (E)-2 hexen-1-ol was identified as one of the major compounds produced as a sex pheromone in the male bug *Pristhesancus plagipennis* which attracts female *P. plagipennis* (James et al., 1994) and has been classified as one of the bioactive compounds which confer medicinal properties on essential oils and is also used in fruit and vegetable flavours and in perfume as it easily isomerizes to (E)-2-hexenal (Valero and Serrano, 2010) while heptacosane (a higher alkane) was identified among compounds which exhibited antibacterial activity (Marrufo et al., 2013; Yogeswari et al., 2012; Mihailovi et al., 2011). It is also possible that addition of one or more of the minor compounds also contribute to the observed bioactivity of the oil since constituents at even very low concentrations have been found to contribute to the aroma, flavour or activity of essential oils. The results could justify the therapeutic used of *M. whitei* root as aphrodisiac and appetizer, as well as remedy for the treatment of an array of diseases.

Most reported bioactivities of *M. whitei* are based on the screening of extracts and active compounds of the plant parts, especially the root with little or no information in literature on the activity of its oil. Watcho et al. (2007) reported the effects of the aqueous and hexane root extracts of the plant on sexual activity of male rats. Also, Patnam et al. (2005) isolated chlorinated coumarinolignan from the roots of *M. whitei*. The plant showed promising *in vitro* antidepressant properties (Pedersen et al., 2008). The non-toxic effect of the plant in mice has also been reported (Kuo et al., 2006).

The essential oil of *M. whitei* root exhibited varied *in vitro* antimicrobial activity against the nine clinical organisms (Table 2). The oil was most active against *Escherichia coli* (50.0 mm) and *Staphylococccus aureus* (48.3 mm) and least active on *Candida albicans* (15.0

Table 1. Components of essential oil of *M. whitei* root.

S/N	Compound	*RI	[+]RI	Composition (%)
1	Cyclohexylmethane	781	-	2.09
2	Toluene	794	785	0.87
3	(E)-2-Hexenal	814	846	4.29
4	1-Hexanol	862	863	8.94
5	(E)-2-Hexen-1-ol	868	859	25.96
6	m-Xylene	907	893	1.56
7	p-Xylene	907	893	0.77
8	1-Octen-3-one	943	969	1.25
9	3-Octanone	952	962	1.37
10	1-Octen-3-ol	969	974	2.24
11	3-Octanol	979	989	2.68
12	Benzaldehyde	982	999	0.21
13	Linalool	1082	1088	3.02
14	2-Methyl-2-nonen-4-one	1136	_	0.69
15	Fenchol	1138	1147	0.21
16	Safranal	1186	1196	0.39
17	β-Cyclocitral	1204	1200	0.21
18	4,4,7a-Trimethyl-2,4,5,6,7,7a-hexahydro-1H-inden-1-one	1371	_	0.41
19	2-Hydroxy-p-anisaldehyde	1392	_	4.21
20	Megastigmatrienone	1454	1462	0.28
21	β-Ionone	1457	1460	2.1
22	Dodecanoic acid	1570	1550	0.46
23	Apiole	1705	1697	0.48
24	Hexahydrofarnesylacetone	1754	1751	0.62
25	Isobutyl phthalate	1908	_	0.36
26	Phytol	2045	2045	15.6
27	Heptacosane	2705	2705	20.94
28	1,2-Cyclohexanedicarboxylic acid dinonyl ester	2965	_	4.96
	Total			99.92

Monoterpene hydrocarbons	0.00
Oxygenated monoterpene	3.62
Sesquiterpene hydrocarbon	0.00
Oxygenated sesquiterpene	2.59
Diterpene	15.60
Non-terpenes	78.12
Total	99.92

Identification of compounds was from gas chromatography-mass spectrometry (GC-MS) spectra, using retention time and mass spectrum. *RI = Retention indices on HP-5 ms capillary column. [+]RI = Retention indices from literature (Adams, 2004) on DBS capillary column.

mm). There was no significant difference in the activity of the oil against *E. coli*, *S. aureus* and *Streptococcus pyogenes*. Also, there was no statistical variation in the oil inhibitory effect against *K. pneumoniae* (36.66 mm), *P. mirabilis* (35.00 mm) and *P. aeruginosa* (35.00 mm) at 10^6 cfu/ml inoculum concentration. The cumulative effect of the oil of *M. whitei* root against nine pathogenic organisms is presented in Table 3. The oil showed significant (P<0.05) inhibitory effect against all the

isolates.

There is little information in literature on the antimicrobial effects of *M. whitei*. However, the present study shows that the antimicrobial effect of the root oil against organisms conforms to previous reports on the anti-infective potential of the extracts of the plant (Gbadamosi and Erinoso, 2015; Okitoi et al., 2007; Fankam et al., 2011). When compared with the findings of Gbadamosi and Erinoso (2015), the antimicrobial

Table 2. *In vitro* antimicrobial activity of *Mondia whitei* root oil.

S/N	Organism (10^6 cfu/ml)	Inhibitory zone (mm)
1	*Escherichia coli*	50.00[a]
2	*Staphylococcus aureus*	48.33[a]
3	*Streptococcus pyogenes*	46.66[a]
4	*Klebsiella pneumoniae*	36.66[b]
5	*Proteus mirabilis*	35.00[b]
6	*Pseudomonas aeruginosa*	35.00[b]
7	*Bacillus cereus*	25.00[c]
8	*Salmonella typhi*	20.00[cd]
9	*Candida albicans*	15.00[d]

Values are mean of 2 readings. Diameter of the cork borer = 6 mm. Means with the same letter in each column are not significantly ($p \le 0.05$) different from one another.

Table 3. Cumulative inhibitory effect of *Mondia whitei* oil against test organisms.

Source	DF	SS	MS	F-value	Pv > F
Model	10	3809.26	380.93	21.23	0.001**
Organisms	8	3796.30	474.54	26.45	0.0001**
Replicates	2	12.96	6.48	0.36	0.7023
Error	16	287.04	17.94		
Corrected Total	26	4096.30			

**Highly significant; $p \le 0.05$.

effect of the extracts (water and ethanol) and oil of *M. whitei* is in the order: root oil > root water extract > root ethanol extract. The root oil could be the most active antimicrobial agent. The antimicrobial activity exhibited by the oil is an indication that the oil could be valuable in the treatment of infectious diseases, especially infections associated with the test organisms used in the present study. The oil could have therapeutic values in the management of urinary tract infections (*E. coli*, *P. aeruginosa* and *K. pneumoniae*), wound infections (*E. coli*, *P. aeruginosa* and *S. pyogenes*), meningitis (*E. coli*, *S. aureus*, *S. pyogenes* and *K. pneumoniae*), ear, nose and throat infections (*E. coli*, *S. aureus* and *S. pyogenes*), dysentery (*E. coli*), fever (*S. typhi* and *S. pyogenes*), pneumonia (*K. pneumoniae* and *S. pyogenes*), septic arthritis (*S. pyogenes* and *P. aeruginosa*) and skin infections (*C. albicans*, *S. aureus* and *S. pyogenes*) (Neugebauer, 1993; Gbadamosi and Oyedele, 2012).

Conclusion

From the results of this study, it is concluded that the volatile oil of *M. whitei* root is very rich in (E)-2-hexen-1-ol (25.96%) and heptacosane (20.94%), the active

compounds might be responsible for the strong antibacterial activity and weak antifungal activity of the oil observed in this study. The findings of the present study could form basis for future research on bioactivities of volatile oil of *M. whitei*, especially on its therapeutic values in the management of infectious diseases such as diarrhoea, bronchitis, urinary tract infection, sexually transmitted infections and skin infections.

Conflict of interests

The authors have not declared any conflict of interests.

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